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NOTES AND MEMORANDA

MOORE'S WORK IN CYCLES: A REVIEW

In 1914 appeared a stimulating volume by Professor H. L. Moore entitled *Economic Cycles: their Law and Cause.* This volume was an attempt to show that the familiar economic cycles of business expansion and depression had their origin in physical phenomena — an attempt at once recalling Professor Jevons' earlier suggestion of a relation between these same economic cycles and sun spots. Professor Jevons' theory, however, would make the length of the cycle approximately eleven years, while that of Professor Moore is based upon a rainfall cycle of eight years.

Since the above-mentioned volume appeared, Professor Moore has continued his studies with enthusiasm and great industry. Students of his method, in addition to the volume above referred to, should read the following articles from his pen: "Forecasting the Crops in the Dakotas," *Political Science Quarterly,* June, 1919; "Crop Cycles in the United Kingdom and in the United States," *Journal of the Royal Statistical Society,* May, 1919; "Crop Cycles in the United Kingdom and in France," *ibid.,* May, 1920; "Generating Cycles of Products and Prices," *Quarterly Journal of Economics,* February, 1921; "Generating Cycles Reflected in a Century of Prices," *ibid.,* August, 1921; and "The Origin of the Eight-Year Generating Cycle," *ibid.,* November, 1921.

The above articles aim to be progressively corroborative of his main thesis, which, in brief, is as follows: An application of Fourier's analysis to rainfall data in the Ohio valley and in Illinois was believed to demonstrate a recurring eight-year cycle superposed upon a thirty-three year cycle. These rainfall cycles were then by an application of Pearson's formula for correlation found to correlate positively with crop cycles and negatively with price cycles. An essential feature in this part of the investigation was a study of demand curves and the relation of crop cycles to price curves. Having once discovered what appeared to be an eight-year cycle of rainfall, Professor Moore in his subsequent articles adduces corroborative evidence of the soundness of his theory by the further discovery of approximately eight-year cycles in crop yields and crop prices in the United States, 1882–1918, with a strong negative correlation between the two series, and, in the same article, demonstrates eight-year cycles in the case of coal and iron production and in raw materials for manufactures.[1] Again, a study of Sauerbeck's index numbers of general wholesale prices, 1818–1913, yields the familiar eight-year cycle,[2] as does also the data for yield per acre of representative crops in the United Kingdom since 1884 [3] and in France.[4] Moreover, the cycles of crop yields in the United Kingdom, in France, and in the United States were found to synchronize. Finally, he quotes from the work of Professor A. E. Douglass, *Climate Cycles and Tree Growth,* in which a study is made of tree rings, in Arizona and elsewhere, in their relation to rainfall, and finds in this remarkable investigation further evidence substantiating his theory.[5] He quotes from an article by H. W. Clough of the United States Weather Bureau, entitled "An Approximate Seven-Year Period in Terrestrial Weather, with Solar Correlation" [6] and also from an official publication of the Weather Bureau, "Report on the Barometry of the United States, Canada, and the West Indies," in which the record of barometric pressure is found to indicate cycles, and an interval of about eight years is found to exist between periods of maximum pressure and like intervals between periods of minimum pressure.[7]

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[1] Quarterly Journal of Economics, February, 1919.

[2] Ibid., August, 1921.

[3] Journal of the Royal Statistical Society, May, 1919.

[4] Ibid., May, 1920.

[5] The quotations from the work of Professor Douglass, as they are made to appear in the Quarterly Journal of Economics for November, 1921 (p. 10), are as follows: "'The interval from 1830 to the present time divides . . . fairly well in (a period) of 7.3 years' (p. 108). As to the whole record of 500 years, he says, 'a 7-year period is also frequently observed' (p. 101). In Table 8 (p. 108) Professor Douglass indicates that his cycle of approximately 7.3 years has been continuous since 1817." It will be noticed that even in these quotations Professor Douglass makes no mention of an eight-year cycle.

[6] Quarterly Journal of Economics, November, 1921, p. 14.

The work of Professor Moore shows an immense amount of painstaking research, and yet in spite of the great wealth of apparently corroborative evidence, I regret to say that I find the work unconvincing.

In the *Quarterly Journal of Economics* for May, 1915, I reviewed Professor Moore's first volume, *Economic Cycles: their Law and Cause,* and was led to question the soundness of his conclusions. I observed that "the eight and thirty-three year cycles were derived from data as to *annual* rainfall, while the whole argument rested upon *effective* rainfall at the critical periods of the growth of the several crops considered." Professor Moore failed to correlate these two. I then discovered that while the data for annual rainfall revealed a fairly well-marked cycle of eight years, the periodogram for effective rainfall showed only very minor indications of an eight-year cycle. There was in the latter case slightly more indication of a seven-year cycle and some indication of a seven-year cycle in the case of the yields per acre of nine principal crops. But in the case of prices the indications were better for a nine, or even a ten-year cycle. Graphs constructed to the seven-year cycle for crops and the nine-year cycle for prices showed an excellent fit.[8] I am repeating here these criticisms from my former review because the whole superstructure of Professor Moore's theory rests upon an *effective* rainfall cycle of eight years and its correlation with crops. It is the "generating cycle" having its origin in non-economic causes upon which all the subsequent economic cycles are made to depend. Therefore, before the rest of the theory can be given much credence, the eight-year cycle of effective rainfall must be firmly established and this Professor Moore has failed to do.

But in his subsequent work, taken by itself without reference to the basis of effective rainfall, there are many matters that call for explanation. I shall select for critical study only a few. In the August number of the *Quarterly Journal of Economics,* a study is made of Sauerbeck's table of index numbers of wholesale prices from 1818 to 1913. This table covers a period of ninety-five years. In it an eight-year cycle would be repeated eleven times. Hence if such a cycle depended upon some regularly recurring natural phenomenon the evidence for it should be unmistakable. Therefore, it has seemed better, in the compass of a review, to make a somewhat detailed study of this table rather than to attempt an exhaustive treatment of all of the alleged cycles discovered by Professor Moore.

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[7] Quarterly Journal of Economics, November, 1921, pp. 16, 17.

[8] Ibid., May, 1915, pp. 634–637.

In the first place, the method of attack is to me unsatisfactory. There is a tendency to apply formulas with uncritical confidence. The successive steps of the process are not enough subjected to the test of observation, independent thought, and reason. Availing himself of a method suggested by Professor Turner, he first regards the whole period as a single cycle of ninety-six years, which cycle he computes and fits to his crude data. He then computes the amplitudes of cycles whose periods are the harmonics of ninety-six, i. e., 48 (one-half of 96), 32 (one-third of 96), 24 (one-fourth of 96), 19.2 (one-fifth of 96), etc., and from the amplitudes so computed selects those of considerable magnitude as referring to periods which may reasonably be assumed to indicate true cycles, and finally he superposes the cycles for such periods one upon another until he evolves a wavy line approximately congruent with his crude data.

Now to employ such a method as this is deliberately to reject the aid which a graphical method affords. One of the chief advantages of a graphical method is that the direct perception of the eye affords suggestion to the reason. These suggestions of the eye must, of course, be mathematically tested and verified, but that is no reason why one should refuse to avail oneself of their aid. The first graph of the crude data makes no suggestion of a ninety-six year cycle, and when such a cycle is constructed it is for more than a third of its course the absolute reverse of a good fit. And why should forty-eight years be selected as the next cycle period in order after ninety-six? It is evident to the eye that the whole period of ninety-five years divides itself roughly into two cycles. But why select forty-eight, rather than forty-nine or fifty? As a matter of fact by a method to be presently explained it was found that fifty-four was the most likely period.

But even if we accept the method of harmonics — and undoubtedly if persisted in far enough it will lead to a curve approximating the crude data — there is one application which he makes of it which is entirely inadmissible Because there are rather large values of A^2 for 8.7 years and for 7.4 years he assumes that the parameter of these cycles may be used for computing the parameters of a cycle midway between them, as follows:

> The eight-year cycle which is representative of the Sauerbeck residuals in Figure 6 was computed from these two equations in the following way: Its period of eight years is the mean of the periods of these two cycles, $\frac{8.73 + 7.38}{2} = 8.05$; the amplitude of the eight-year cycle is the mean of the amplitudes of these two cycles,
>
> $$\frac{3.8 + 3.1}{2} = 3.45;$$
>
> and the phase of the eight-year cycle is the mean of the phases of the two cycles, $\frac{9^\circ + 92^\circ}{2} = 50^\circ\ 30'$.[9]

It is singular how Professor Moore could have rested his case for an eight-year cycle on such reasoning when in his own table on page 525[1] he had directly before his eyes the square of the amplitude of the eight-year cycle, 2.12, the square root of which, or the amplitude of the eight-year cycle, far from being 3.45, is only 1.45. The method is demonstrably false. Suppose our crude data formed the ordinates of a perfect cycle whose period was eight years. Now suppose we used these ordinates as the crude data to which were to be fitted cycles whose periods were respectively between eight and nine years and between seven and eight years. Obviously, these cycles being a poor fit would both show a less amplitude than that of the eight-year cycle which was a perfect fit. Hence the mean of their amplitudes could not be equal to that of the eight-year cycle but would be less. As will presently be shown, a cycle of nine years shows a larger amplitude than either 8.7 years or 7.4 years, viz. 4.143, the square of which is 17.16. That is, the cycle of best fit lies between the harmonics 8.7 years and 9.6 years, with an amplitude greater than either of them, as, in theory, it should be. I think it not unlikely, judging from the appearance of the graph (tho I have not made the computation), that a cycle of fairly good fit for a portion of the distance would be found to lie between the harmonics 6.9 years and 7.4 years with an amplitude greater than either.

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[9] Quarterly Journal of Economics, August, 1921, p. 522.

[1] Ibid., p. 525.

When the Fourier theorem is applied to such a series of ordinates as is provided by Sauerbeck's index numbers, a period of practically any number of years will yield a sinusoid of some amplitude, greater or less. This is shown in all of Professor Moore's periodogram tables. But do any of these sine curves represent a real periodicity in nature? Professor Moore himself raises this question. On page 505 he says: "When the parameters of this equation [$y = A_0 + A_1 \sin(kt + e_1) + A_2 \sin(2kt + e_2) + \ldots$] are determined from statistical data the question arises as to the significance of the several terms of the Fourier series. Do the successive terms in the sine series correspond to real periodicities in nature, or are they merely formal terms the summation of which will give the observed values of the original data?"[2] In answer to this question he accepts Professor Schuster's conclusion which, in brief, is that "the probability of the reality of an assumed cycle is . . . dependent upon the relative size of A^2 where A is the coefficient of the sine term descriptive of the assumed cycle." Since A is the amplitude of the cycle, this means that the probability that a cycle is based upon a real periodicity in nature increases in proportion to the squares of the relative amplitudes of the cycles. This may be accepted, but it should be remembered that it is only a probability, not a demonstrated fact. I shall presently show that the amplitude may be very considerable in a case where it is practically certain that no periodicity in nature exists, and in the case before us of Sauerbeck's index numbers I shall show that it is doubtful whether a certain cycle of considerable amplitude represents a real periodicity. The fit of a Fourier cycle becomes convincing only when the reasoning proceeds in the opposite direction. Let some periodicity in nature, such as sun spots or the conjunctions of Venus, be firmly established by independent reasoning, and let some causal relation based upon known physical principles be shown to exist between these phenomena and the phenomena under investigation, then an identity of Fourier cycles of large amplitude becomes strong corroborative evidence of the correctness of our reasoning. Having established the rainfall cycle we may proceed to crop yield and business cycles. This, indeed, in the main is the method pursued by Professor Moore, except that he does not discuss the alleged cosmic cause, conjunctions of the planet Venus, until all of the other derived cycles have received attention.

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[2] Quarterly Journal of Economics, August, 1921, p. 505.

To discover, so far as could be discovered by merely investigating for amplitude, the probability that the Sauerbeck index numbers represented real periodicities in nature, I availed myself to a considerable extent of the advantages which a graphical method affords of suggesting conclusions to the eye, afterwards checking these conclusions by a mathematical analysis. I plotted the crude data as shown in Figure 1. A general downward trend is clearly discernible for the whole period from 1818 to 1913. To investigate for cycles it seemed desirable to eliminate this trend. I accordingly fitted a straight line to the crude data by the method of least squares and then referred the price curve to this trend as an axis of abscissas as shown in Figure 2. Inspection of the diagram now makes it apparent that the whole period covers approximately two major cycles of prices. Beginning at the extreme left there is a general downward movement of prices for about a fourth of the distance, then a general upward movement to the center, then downward and then upward to the extreme right. To discover the period of this cycle which would best fit the crude data I correlated by Pearson's formula $\left(r = \frac{\Sigma(xy)}{n\sigma_1\sigma_2}\right)$ each term of the series with its fiftieth, then with its fifty-first, then with its fifty-second, and so on. I found the coefficient of correlation highest when I correlated each term with its fifty-fourth, the coefficients

FIG. 1

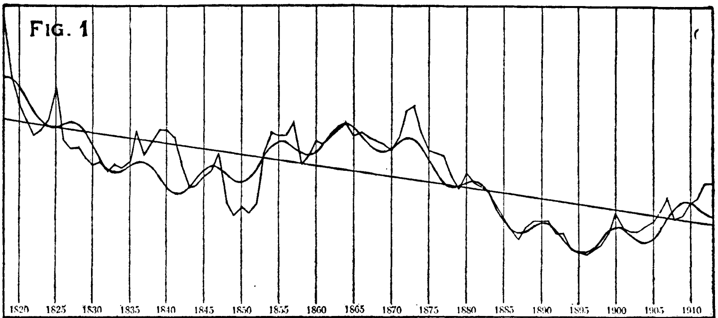

FIG. 2

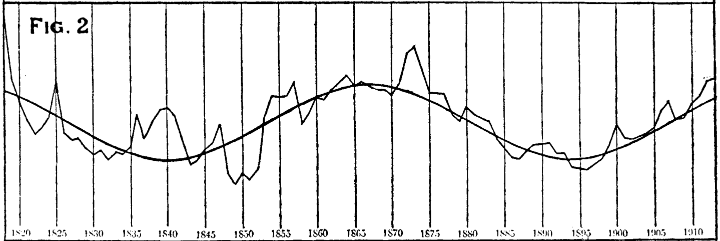

FIG. 3

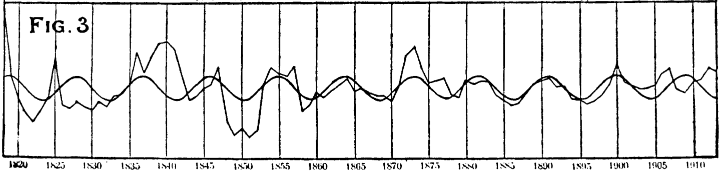

FIGURE 1. Graph of crude data of Sauerbeck's index numbers, 1818–1913, with trend [$y = 106.5 - 0.3784t$] and fifty-four and nine year cycles superposed thereon [$y = 106.5 - 0.3784t + 12.429 \sin(122° 51' + \frac{360}{54}t) + 4.143 \sin.(55° 53' + \frac{360}{9}t)$].

FIGURE 2. Sauerbeck's index numbers plotted to trend as an axis of abscissas and fitted with fifty-four year cycle, [$y = 100 + 12.429 \sin(122° 51' + \frac{360}{54}t)$].

FIGURE 3. Sauerbeck's index numbers plotted to fifty-four year cycle as an axis of abscissas and fitted with nine year cycle, $y = 101.3 - 4.143 \sin(55° 53' + \frac{360}{9}t)$.

decreasing as the interval of separation between the terms correlated was greater or less than fifty-four. At fifty-four the result was $r = 0.5725$. This led me to believe that the first major cycle of best fit was one with a period of fifty-four years. I accordingly computed by Fourier's formula its equation ($y = 100 + 12.429 \, sin \, (122° \, 51' + 6° \, 40' \, t)$) and plotted it with the result shown in Figure 2. Again referring the data to this sinusoid as an axis of abscissas, the original data assumed the form shown in Figure 3. Inspection now led me to suspect a cycle of about nine years for a considerable portion of the period, tho it was clear that at the beginning a longer cycle of some nineteen or twenty years would make a better fit and at the end a cycle of shorter period — about seven years. I tried correlating by Pearson's formula each term with its seventh, its eighth, its ninth, its tenth, and its eleventh. The ninth gave the highest correlation, tho even in this case the result was negative ($r = -0.1102$). As it was larger than any of the others, however, I tried fitting a nine-year cycle to the crude data and obtained the equation $y = 101.3 + 4.143 \, sin \, (55° \, 53' + 40° \, t)$. The curve was then plotted with the result shown in Figure 3. Now it will be observed that beginning about 1845 and continuing to about 1903 the nine-year cycle follows the ups and downs of the crude data with clinging fidelity. For the first twenty-seven years, however, and at the end of the curve the fit is poor. Indeed, there may be said to be no fit at all. Yet the Fourier formula for the whole period developed a cycle of very considerable amplitude (4.143), a value considerably larger even than that obtained by an erroneous method which Professor Moore accepted as indicating a real cycle of eight years (3.45) and nearly three times as large as that which he shows in his table on page 525 to be the true amplitude of the eight-year cycle ($\sqrt{2.12} = 1.45$). If the squares of these amplitudes are compared (and it will be remembered that it is the squares which Professor Schuster regards as significant) the evidence in favor of the nine-year cycle is even more pronounced. Nine-year cycle, 17.164; eight-year cycle (erroneous method), 11.902; (correct method), 2.12.

Yet in spite of the large amplitude of the nine-year cycle I am skeptical as to its indicating any real periodicity in nature. Had the price data been collected only from 1845 to 1903, the evidence of a real periodicity (so far as a Fourier cycle can give such evidence) would have seemed conclusive. The large amplitude, the perfect fit, would have left little to be desired. Yet with the whole period before us the case is otherwise and serves to show how misleading may be the method even when applied to crude data for so long a period as fifty-eight years — over six complete cycles. With the whole ninety-five years before us, we see that the nine-year cycle bears no resemblance to the data for the first twenty-seven years nor for the last nine years. A true periodicity in nature should not fail so utterly to manifest itself through so great a part of the ninety-five years as thirty-six — more than a third of the entire period. During the first part of the curve it is apparent that a cycle of about nineteen years would make a fair fit. It will be noticed that in the table on page 525 the value of A^2 for the period of 19.2 years has the high value of 28.23. The truth appears to be that when we have a considerable series of years, as in the case of Sauerbeck's index numbers, if a cycle shows a good fit throughout a portion of the period, it may, when computed by the Fourier formula, show a large amplitude even tho the fit throughout the remainder of the curve is very poor. I am inclined to think that the method of testing by correlations is somewhat more sensitive. As stated above, when applying the method of correlation, and using as subject and relative numbers in the series separated by an interval of nine years, the coefficient of correlation for the whole ninety-five years of the Sauerbeck table was negative, $r = -0.1102$. When applied to the first twenty-seven and the last eighteen years, the results were even more strikingly negative, $r = -0.4425$ and $r = -0.5046$ respectively. But when applied to the fifty years following the first twenty-seven, the period wherein the fit is obviously so good, the correlation was strongly positive, $r = +0.7001$.[3]

[3] It must be admitted that the evidence for a real periodicity in nature for the nine-year cycle from 1845 to 1903 is very strong. The large value of r (0.7001), the

To show that in the case of a series of crude data so chosen as to preclude the possibility of a true periodicity in nature, the Fourier analysis may yet seem to indicate such a periodicity, the following experiment was tried. A die was thrown fifty times and the number of pips on the face falling uppermost was plotted after each throw. To preclude any juggling for results the first fifty throws were taken. The curve was fitted to a straight line trend by the method of least squares, and then to cycles of five years, as shown in Figures 4 and 5.

FIG. 4

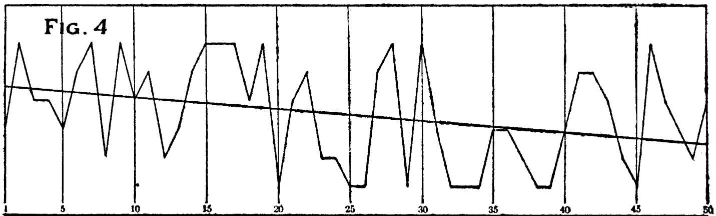

FIG. 5

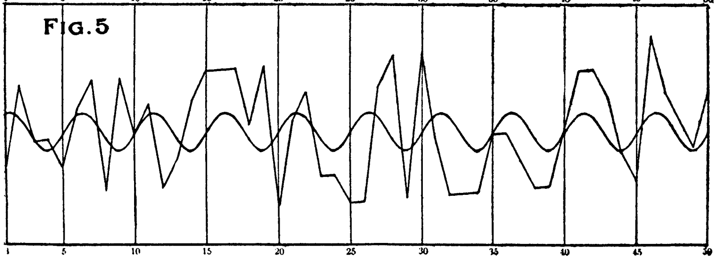

FIGURE 4. Graph of fifty throws with a die and trend, $y = 4.46 - 0.03913t$.

FIGURE 5. Graph of fifty throws with a die plotted to trend as an axis of abscissas and fitted with five year cycle, $y = 10 + 0.66 \sin (60° 21' + \frac{360}{5}t)$.

The double amplitude of the cycle as compared with the extreme range of the crude data was very nearly as great as in the case of the nine-year price cycle just discussed. Die-

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small value of the probable error (0.0486), and the observed close fit of the curve to the crude data indicate a relation so close as almost to preclude accident. If as suggested in the closing paragraph business and price cycles are due to cyclical recurrences in mass psychology reacting through capitalistic production, it appears as tho during this period of nearly sixty years the psychologic sequence ran its course in nine years. The diagram suggests to the eye a tendency for the cycle gradually to shorten. Previous to 1845 the period is longer than nine years and after 1900, less than nine years. The amplitude also tends to grow less. At any rate the diagram is sufficiently suggestive to call for a more detailed study than can be given to it in the compass of a review.

It may be noted that in the case of general prices in the United States (1870–1910) the nine-year cycle showed the best fit. See Quarterly Journal of Economics, May, 1915, pp. 635–637.

throw cycle, 22 per cent; price cycle, 25 per cent. At no part of the curve is the fit so good as that of the nine-year cycle from 1845 to 1903 in the case of the Sauerbeck index numbers. It is, however, about as suggestive of a true periodicity in nature as the eight-year cycles for rainfall shown on page 13 of the November issue of the *Quarterly Journal of Economics.*

As was stated above Professor Moore adduces certain quotations in support of his theory from the work of Professor A. E. Douglass on tree rings. But these quotations leave an entirely erroneous impression of Professor Douglass' work. It is true that he does find evidences of minor cycles of about eight years (not of precisely eight years, however) but such cycles are not deemed of sufficient importance by him to be even mentioned in the final summary of his work. What Professor Douglass does find and what he makes prominent in his summary is the sun-spot cycle of 11.4 years. On page 85 he says:[4]

> We shall find that the sun spot cycle plays an important part in rainfall.

And in the final summary, these words:

> (7) Practically all the groups of trees investigated show the sun spot cycle or its multiples; the solar cycle becomes more certain and accurate as the area of homogeneous region increases or the time of a tree record extends further back; this suggests the possibility of determining the climatic and vegetational reactions to the solar cycle in different parts of the world.
>
> (8) A most suggestive correlation exists in the dates of maxima and minima found in tree-growth, rainfall, temperature, and solar phenomena. The prevalence of the solar cycle or its multiples, the greater accuracy as area or time are extended, and this correlation in dates, point toward a physical connection between solar activity and terrestrial weather.

In my former review of Professor Moore's work and methods I used these words:

> The suggestion is offered that before any cycles relating to rainfall can be regarded as conclusive, some adequate astronomical or meteorological cause should be adduced.[5]

[4] Climatic Cycles and Tree Growth, A. E. Douglass.

[5] Quarterly Journal of Economics, May, 1915, p. 638.

The necessity of demonstrating some such basis in the physical universe is made more apparent by the test of the die throws given above. A cycle of fairly good fit was demonstrated for a period comparable to fifty years of rainfall. Yet the fall of a die is pure chance. It might, therefore, well happen that a cycle of large amplitude should adjust itself to the rainfall for a considerable number of years and yet the annual rainfall be dependent upon chance. Another selected period might show a cycle of very different amplitude and wave length, or no cycle at all. Such a situation is clearly suggested in the analysis of Sauerbeck's index numbers. The nine-year cycle made a remarkably good fit for fifty years, but no fit at all before or thereafter. The law governing price index numbers from year to year may, so far as the diagram proves anything, be the law of chance.

If, however, a recurring sequence of an astronomical character can be demonstrated and a causal relation between it and terrestrial phenomena shown to exist, the case is much strengthened. It is a merit of the 11.4-year cycle for rainfall that it correlates with the sun-spot cycle generally accepted by astronomers. The observed effect upon terrestrial magnetic and electrical phenomena suggests that there is a causal relation in some directions but the matter cannot yet be said to have been cleared up.

Professor Moore has recognized the need of an astronomical basis. In his contribution to the November issue of the *Quarterly Journal of Economics* he proposes such a basis for the rainfall cycle in the conjunctions of Venus. He explains at some length the motions of the planet relatively to the earth, and lays stress upon the peculiar climate of Venus, due to the fact that its axial rotation synchronizes with its orbital period of revolution, as having a possible effect upon terrestrial rainfall. In seeking an astronomical cause he is on the right track, but before the Venus theory can be taken seriously, it is incumbent upon him to explain in much more detail the process by which either the conjunctions or the meteorological conditions of Venus can affect the earth. The earth's meteorological phenomena are undoubtedly effects of solar energy, but even at a true conjunction at a time of transit the body of the planet appears as merely a small black spot against the sun's disk. Frequently a single sun spot exceeds it in size. The last transit occurred on December 6, 1882, and there will not be another until January 8, 2004. At ordinary conjunctions the rays of solar energy passing through the planet's atmosphere miss the earth by many thousand miles. The rays that do strike the earth do not pass through the planet's atmosphere and it is difficult to see how they could be in any way affected by conditions therein. The planet must exert a gravitational influence upon the earth, deflecting it from its normal orbit slightly towards the sun at a time of conjunction. It is conceivable that this deflection would slightly increase the quantity of solar energy received and hence the rainfall. Still, it is unlikely that the effect from this cause would be appreciable. On the whole it would seem that if Venus exerts any appreciable influence upon the earth's climate, such influence must be ascribed to astrological rather than astronomical causation.

In conclusion, it appears to the writer, that while it is always a fascinating pursuit to seek a physical basis for economic and sociological phenomena, in the present instance it is not necessary, in order to account for the roughly periodic ups and downs of business, to assign any such non-economic generating cycle. Adequate causal forces may be found in the capitalist system with its production in anticipation of demand, its constant influx of labor-saving machinery, and its foundation upon a basis so non-material and so subject to the swift mutation of group psychology as credit. Indeed, the rough periodicity of business cycles suggests the elastic recurrence of human functioning rather than the mathematical precision of cosmic phenomena.

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